ENVIRONMENTAL RISK MANAGEMENT BASED ON ROUGH SET THEORY USING EMAS RELEVANT RECOMMENDED INDICATORS

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The article presents the possibility to use Rough Set Theory (English acronym RST) to manage environmental risk using EMAS III relevant recommended indicators. The general considerations about how to use the theory as a new instrument in order to take environmental decision in uncertainty conditions within organization EM system to increase organization management performance are presented.

Keywords: RST, EMAS III

1. Introduction

The article presents the possibility to use Rough Set Theory (English acronym RST) to manage environmental risk using EMAS III /EC Regulation No. 1221/2009 relevant recommended indicators (EMAS III English acronym for Eco Management and Audit Scheme).

The environmental risk management within an organization means taking responsibility for the occurrence of the possible environmental negative consequences by enforcing the appropriate environmental protection measures in order to reduce the environmental risk at an acceptable level This acceptable level is negotiated for opportunities and benefits for the development of local economic activities.

The economic local development should be realized in a sustainable manner with maximum achievable health and safety protection. Risk management is most of the time contextual linked to political, cultural and economic values and depends on the organization management risk appetite. Environmental risk management means taking decision in uncertainty conditions. Therefore having a reliable instrument to support and document the environmental decision should be well received when taking into consideration environmental issues because final liability for possible occurrence of greater severity consequences will be charged on the organization itself according to the polluter pays principle. That means that monitoring environmental performance is a way to prevent pollution consequences not only at local level but also at regional level and EMAS III indicators are meant to help organization to acquire such performance while keeping the organization profitability and even increasing its market share through a performing environmental risk management. The article is organized in three sections as follows:

1 - *A short background of the RST as decision support in uncertainty conditions*,

2 - *The possibilities to support the organizational environmental risk management decisions based on Rough Set Theory using EMAS relevant recommended indicators*

3 - *Benefits of using RST/EMAS III indicators approach in realizing the desiderates of the sustainable developments.*

2. Short background of the RST as a decision support in uncertainty conditions

Environmental impact assessment is one of the endeavor that should be taken into account according to environmental national, European and international legislation both at the beginning of a new project organization development or any time when changes in the organization operations requires this endeavor. EIA (English acronym for Environmental Impact Assessment) can be defined as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals before major decisions are taken and commitments made" [1]. This way the existing or possible future pollution issues related to a significant environmental impact that determines the exceeding of the regulated intervention limits are considered in order to evaluate the environmental risk linked to the organization activities.

The environmental risk assessment and appropriate measures to manage it should be realized for any organization on regular basis when, following the monitoring site pollution for a relevant period of time, the allowable environmental legal concentrations were exceeded due to: changes in the organization activities, the local pollution context changes (increased pollution from up stream of the organization site) or incidental/accidental pollutants releases. Using EMAS III indicators to monitor the organization environmental performance can be used in conjunction with RST in order to produce a performing environmental risk management. Developed in '80 by polish Z. Pawlak, Rough Set Theory became a potent mathematical instrument to be used in objects/observations/states/events classification. When objects/observations/states/events are characterized by a set of finite characteristics they can be presented in a table named information system. The information from the table can be processed and can be organized in a new relevant/significant way for a certain topic so that hidden regularities, can be revealed and increase our knowledge about the considered topic. RST considers a non-empty set of objects/observations/states/events denoted **U** named universe of discourse characterized by a finite number of attributes/features that form another set denoted F. Through their chosen attributes/features, objects/observations/states/events are used to describe a certain topic. "Strictly speaking, the set **U** should be an infinite one but, because in real world in most cases we cannot get all objects in it, RST considers only a finite, non-empty sample set denoted U included in the whole universe U $\subseteq$ **U** [2]. Basics of RST can be summed up as follows: the information about a set of objects/observations/states/events is defined as information system represented by a 4-tuple S = (U, F, V, ρ) where:

U - is a finite non-empty set of objects/observations/states/events called universe of discourse

F - is a finite non-empty set of features characterizing objects/observations/states/events from U

$V= \cup_{f\in F} V_f$ - is a non-empty set representing the union of features value domains, for attribute $f\in F$,

ρ: U X F → V is the information function, ρ (x, f) that maps one object x ∈ U to one value of "f " from V_f [3]

For any subset T ($T \subseteq F$) of features "f " from F one can define an equivalence relation, $E \subseteq U X U$ that is reflexive (xEx), symmetric (xEy yEx) transitive (xEy, yEz zEy) named indiscernibility relation and denoted IND (T) = $\{(x, y)| \ \forall \ t \in T \rightarrow \rho \ (x, t) =\rho \ (y, t), \ x, y \in U\}$. Otherwise saying, for the objects/observations/states/events of the U, there are subsets T of attributes/features $T \subseteq F$ that make these objects/observations/states/events indiscernible one from other. If the available information given by those subsets of features T - that characterize the objects/observations/states/events represents all the available information (because that is all it is known or all knowledge accessible to us at a certain moment about a certain topic) - that represents actually the upper level of our knowledge and then objects/observations/states/events look to us the same. With equivalence relation E = IND (T) introduced by the subset of features T, the universe U can be partitioned into a collection of equivalence classes U/IND(T) denoted also as U/T.

The *equivalence classes* introduce by indiscernibility relation E=IND(T) represents the building blocks of the RST. Each equivalence class is called an elementary set with respect to subset of attributes/features T and forms an elementary granule of knowledge about the considered universe. If a set is made only of *union of elementary sets than the set is definable.* By taking union of elementary definable sets, one can derive larger definable sets. *The family of all definable sets contains the empty set ∅, and whole set U.* For an equivalence relation E, the pair (U, E) is called an approximation space. Equivalence classes are the elementary definable, measurable or observable sets in the approximation space (U,E). In the approximation space we only have a coarsened view of the universe. Each equivalence class is considered as a whole granule instead of many individuals because those individuals are indiscernible each from other in the light of the set of attributes/features that induced equivalence classes. Finally using RST means to analyzes the entrances in such a table and shows that if all the features have the same values - the same entrances in the table - then the objects/observations/states/events describing a certain topic should be indiscernible with reference to those attributes/features for a class. RST is a powerful classification instrument. This way, RST determines classes of indiscernible objects/observations/states/events that can be used in diagnosis and prediction [4]. However, there are situations when objects/observations/states/events having equal description with reference to a set of attributes/features called condition attributes/ features are classified in/assigned to different sets of attributes/features called decision attributes/features or classes. This brings uncertainty about the information linked to those objects/observations/states/events. To deal with such situations RST introduces in algorithm of pre-processing data that is able to select/summarize/reduce data to the minimum necessary for a certain purpose. The reduction can be made in the S by rows or by columns obtaining finally RST informational reducts using definitions such as:

- consistent objects/observations/states/events are those that for the same conditional features the decisional features are the same;
- inconsistent objects/observations/states/events are those that for the same values of conditional features have different values of the decision features;
- degree of consistency is the ratio of the number of objects / observations / states / events adequate classified and the total number of the objects/observations/states/events.

The least minimal subset which ensures the same quality of classification as the initial set of all attributes/features is named reduct. An information system may have more than one reduct/minimal set. Intersection of all reducts/minimal sets is called core. The core is the collection of most significant attributes/features for the classification system/classification table. The elementary sets generated by the decisions' attributes/features are called classes and define actually the concepts. Concepts that can be written as union of elementary sets are called precise concepts and they are expressed as crisp (precise) sets otherwise they are vague concepts and they are expressed as vague, imprecise, or rough sets. A set, in the view of elementary set theory can be crisp when an element based on certain properties clearly can be part of the a set or not. A set in the view of Rough Set Theory is rough when an element of it cannot be classified without doubt as being part of it. Such a set describes actually a so called rough concept and shows that, based on available information an element cannot be classified as being part of that concept. Any rough set has border / boundary-line cases, i.e., objects / observations / states / events which cannot be classified with certainty either as members of the set or of its complement while crisp sets have no border/ boundary-line elements. In the light of the available information about them border/boundary-line cases cannot be properly classified. RST proposes that any vague concepts can be replaced by a set of precise concepts called the lower and the upper approximation of the vague concepts. This way RST transform the vagueness of the rough concept to the uncertainty expressed in its boundary region (Pawlak 2007 cited in [5]).

3. The possibilities to support the organizational environmental risk management decision based on Rough Set Theory and use of EMAS relevant recommended indicators

RST can be successfully used in risk identification, risk analysis and risk assessment, the essentially three steps of any risk assessment including environmental risk in order to **find decision rules to classify the assessed**

risk and to allow early warning and mitigation/reduction measures so a good environmental risk management to be realized. If relevant indicators are used as attributes within RST type table to characterize objects/observations/states representing the environmental possible pollution organization states, relevant pollution risk management rules can be derived to show the pollution evolution. The RST algorithm allows the reorganization of data but the most important capability is actually the attributes' reduction. "Rough sets can be used to reduce the number of attributes contained in the data set using the data alone, requiring no additional information"[3]. When indicators of class 1, 2, 3... etc for example have certain values, management decision rules can be induced. This way, RST represents a useful classification tool based on available information at certain moment. Using an algorithm of pre-processing raw data, a useful selection of the raw data can be realised. Different relations among reduced data (useful EMAS indicators) can be derived in the form of decision rules applying RST algorithm. They are of type "if ...then" rules, i.e. "if condition attributes" then "decision attributes", they are simple and they are useful for the decision maker to assess the significance of the pollution level based on a set of significant chosen indicators that synthesize a sum of relevant information so that the trend in pollution evolution and pollution risk for each organization can be identified. Each organization should have set of environmental indicators proper to its activities/products/services used to report its performance in the most relevant way and reveal the environmental risk associated to the possible significant impact in order to take appropriate measures to reduce it [6] . The literature in the field [7] "defines the environmental indicators as being:

a) the measures of the system behavior in terms of perceivable and meaningful attributes;

b) the measures that sum-up the relevant information for a particular phenomenon, or for a reasonable proxy of it;

c) the parameters, and the derived value from parameters, that emphasize and offer information about a phenomenon/media/area with extended significance beyond to that direct observed or associated with a value of the parameter (a measured or observed property);

d) the variable that describes the system, where the variable is an operational representation of an attribute (quality, characteristic, property) of a system".

ISO 14001 standard and EMAS I and II require the construction of such relevant environmental indicators and ISO 14031 standard offered even a general guide [8] in order to emphasize the cause – effect relationship for pollution due to organization's activities/products/services. Indicators can be classified in two big classes Environmental Performance Indicators and Environmental Conditions Indicators. Taking into account the environmental conditions as reference, the organization can establish potential impacts and can plan to implement the preventive and protective adequate measures. In relation with those indicators EMAS III requires that indicators should be reported with reference to quantities relevant to the organization's dimensions and activities such as: the annual organization gross value added, the annual organization turnover, the annual organization quantitative output (in tones for example), the average annual number of employees and requires a number of EMS cores indicators that shall apply to all types of organizations. The required indicators should focus on performance in the following key environmental areas: energy efficiency, material efficiency, water, waste, biodiversity, emissions. With those types of indicators a scheme of general environmental risk management using RST can produce as in Fig. 1. First available indicators with their value are collected and an information system is presented. Afterwards the relevant indicators are selected in order to emphasize the trend of pollution for the corresponding environmental segment (water, air, soil etc). Environmental indicators are usually taking into consideration as conditions attributes to decide if there is a significant environmental impact/environmental risk depending were they are positive/negative markers for the environmental states defining risk decision rules/risk classes according to the possible values of the selected attribute/EMAS III indicators. There can be defined risk classes such as in Fig. 1 example with the following significance, although any other scale can be taken R_N where N = 0÷5, 0 = no risk, 1 = very small, 2= small, 3 = medium, 4=big, 5=very big. When new data should be introduced, the data compatibility is checked. If the data are compatible the decision rules for the Decision System are used. If not, the scheme shows the steps that should be taken in order to be possible to use. New indicators can be entered and new type of problem solving formulation can be added. Some of the inducted decision rules can be deterministic rules (certain decision rules) some of them can be non-deterministic rules (possible decision rules). When the decision rules are certain the scheme from Fig. 1 shows that the risk decision class is selected and the appropriate mitigation measures are taken at moment t_k as well as at following moments t_{k+1} that should evaluate the pollution evolution and the evolution pollution consequences probabilities making this way possible to adjust environmental risk management decisions in the most flexible way. Some of the inducted decision rules can be non-deterministic (possible decision rules) and in this case a set of appropriate possible mitigation measures are taken also at moment t_k as well as at following moments t_{k+1} that should evaluate the other decisions rules about risk classes that are not certain but possible. Those should complement the certain rules and offers a larger view in taking environmental decision in uncertain conditions. If the indicators remains unchanged from the moment t_k and t_{k+1} the same measures as last time remain in place. This way the system allows risk communication on short and long term notice [9].

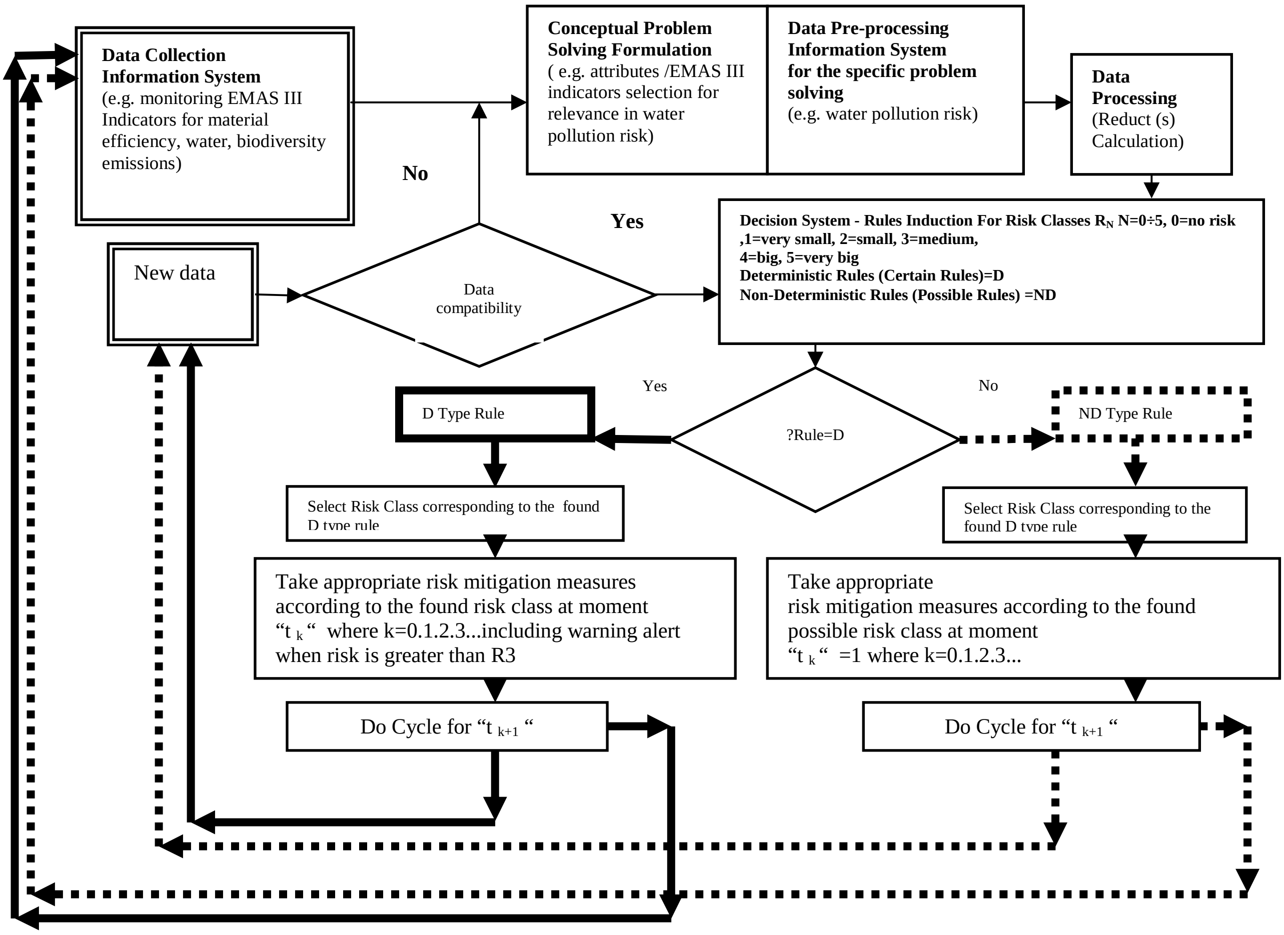

Fig. 1 General environmental risk management scheme using RST

4. Benefits of using RST/EMAS III indicators approach in realizing the desiderates of the sustainable development.

Benefits of using such an approach in realizing the desiderates of the sustainable development that are related to the fact that recommended monitoring indicators can become a useful tool to compare different environmental performances from different organization. The management has the possibilities to document their decision in uncertain conditions and a scheme such the one presented in Fig. 1 can easily be supported by a computerized frame without special computation needs. The risk decision rule formed based on reduct properties can be used to automatically judge new data. The model can be improved and verify. Its advantages is that using RST it can use incomplete data being able to analyze them and to identify dependencies between data and get regularities from experience. Rough set theory can easily combine with other data analysis methods such as fuzzy theory, neural networks and other methods using large amount of historical data [9].

5. Conclusions

The general considerations about how to use RST as a new instrument in order to take environmental decision in uncertainty conditions within organization EM system to increase organization management performance are presented using EMAS III type of indicators. It is a useful tool that can be easily automated without special computational needs that can be used in any organization that can report this way the results in a harmonized comparable manner.

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